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OPTICAL TESTING ON THE NOVA LASER FUSION PROGRAM

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OPTICAL TESTING ON THE NOVA LASER FUSION PROGRAM*

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Introduction

NOVA is a ten-beam, seventy-four cm output aperture Neodymium: fluorophosphate laser designed to perform laser fusion experiments at 1054 nm wavelength 80-120 Kilojoule and 100 ps to 3 ns pulse length. The cost of the initial phase is $134M with approximately 90% of that being for outside procurement. The laser contains several thousand optical elements including polarizing beamsplitters, laser rods and amplifier disks, aspheric lenses, spatial filter lenses and turning mirrors.

The optical testing part of the program requires characterizing index homogeneity of large blanks of fluorophosphate glass, optical surface figure and quality of large polished optics and performance of optical coatings such as antireflection, high reflectors and polarizing beam-splitters. For this purpose, a large effort is being expended to upgrade the optical test facilities at Lawrence Livermore Laboratory in preparation for the NOVA optics procurement.

The optical facility will be used to evaluate the following parameters:

1. index homogeneity
2. stress birefringence
3. surface quality
4. reflected & transmitted wavefront distortion
5. damage threshold
6. reflectance and transmittance

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NOVA OPTICAL CHAIN

NOVA is a ten beam, 74 cm output aperture Neodymium-glass laser to be used at the High Energy Laser facility at Lawrence Livermore Laboratory. The amplifying medium is fluorophosphate glass which was developed especially for this program.

The fluorophosphate glass has a Low non-Linear index of refraction. Most of the fluorophosphate glass is designed to be used at Brewster's angle, thus eliminating the need for coatings. The remaining fluorophosphate glass is in the form of rod amplifiers. BK7 and fused silica is used for debris shields, spatial filter lenses, etc. The largest amplifier disk is 46 cm effective aperture and is split into two halves for the suppression of fluorescent depumping. The final turning mirrors are about 1 m diameter and fabricated from BK7.

The NOVA optical chain is shown in Figure 1. The use of the new fluorophosphate glass and large apertures requires advanced techniques for testing of large optical components on both the component and sub-assembly levels.

OPTICAL TESTING ON THE NOVA PROJECT

It is the philosophy of the NOVA project that the optical component be tested for conformity to specification at the vendor or supplier wherever possible. In some cases, the optical test equipment is provided to the vendor where it is desirable, e.g., Comparative Damage Test Facility.

The major optical test equipment required to do the job is listed in Table I.

TABLE I

Equipment	Parameter Tested	Wavelength
Oil-on-plate tester	index homogeneity	633 nm
20 cm Twyman-Green Interferometer	wavefront distortion	1064 nm
40 cm Fizeau Interferometer	wavefront distortion	633 nm
80 cm Fizeau Interferometer	wavefront distortion	633 nm & 1064 nm
46 cm Polariscope	stress birefringence	540 nm
1 m Scanning Reflectometer/ Transmissometer	R & T	633 nm & 1064 nm

OIL-ON-PLATE TESTER

The oil-on-plate tester is a device for oiling high quality optical windows to optical glass material or other flat optics to eliminate the optical surfaces of the piece under test. Thus, the interior volume of a fine ground optical blank can be examined for index homogeneity and stress birefringence when this device is used in conjunction with an interferometer and polariscope, respectively.

The advantages of this device over the conventional technique are: the oil is contained in a cavity, the plates are moved by fluid pressure and easily separated when the cavity is flooded with oil. The oil-on-tester is shown in Figure 2. The part to be tested is suspended in the cavity by appropriate fixtures. The air vent is opened and index matching oil is pumped into the cavity to a level which completely immerses the part to be tested. The air vent is closed and oil is pumped out of the cavity which causes atmospheric pressure to push the moveable window towards the part. In order to prevent the window from cocking at an angle, the window motion is followed by three adjustment screws all of which are coupled by a flexible chain and sprockets. The two oil-on-plates are thus brought into contact with the part under test. The air vent is opened and the excess oil is pumped from the cavity leaving thin films of index matching oil between adjacent optical surfaces. The oil films are supported by the surface tension of the oil at the oil-air interfaces. The surface tension, wetting angle and film thickness determine the maximum height of oil that can be supported vertically. The surface tension, T, may be defined as the force acting on one side of a straight line of unit length in the surface. It acts parallel to the surface and perpendicular to the line. The cross-sectional view of the oil film between two optical surfaces is shown in Figure 3. The maximum height, h, of oil that can be supported by the vertical component of surface tension, T cos , is given by $2LT\cos\theta = dLh\rho g$, or,

$$dh = \frac{2T\cos\theta}{\rho g} \tag{1}$$

where ρ is the oil density, g is the gravitational acceleration, d is the plate separation, θ is the oil-glass contact angle, and T is the surface tension. For two cases of index matching oil and BK7 glass the values are given in Table II.

TABLE II

n	θ deg	T $\frac{\text{dynes}}{\text{cm}}$	ρ $\frac{\text{gm}}{\text{cm}^3}$	d/h cm^2
1.46	10°	66	.96	.14
1.51	7°	107	1.15	.19

The values of d•h in Table II describe the relationships between capillary height versus plate separation for a typical index matching fluids. The plates must be separated by a distance less than about .002 cm to support a 1 meter high oil film. One meter is about the practical limit in height for supporting a vertical oil film between two glass surfaces. The plates can be physically separated by pumping oil into the cavity with the air vent closed. The presence of excess oil makes oil capillarity disappear which aids the plate separation. If the cavity is not flooded with oil it is very difficult to separate the plates. If the part to be tested is irregular or wedged, the oil-on-plates can be made parallel with the use of three precision ground pins which are held perpendicular to the flat surfaces of the plates. The plates are brought in contact with the ends of the three pins which are in line with the three adjusting screws. The oil is left in the plane parallel cavity along with the part to be tested. Experiments with a 25 cm aperture oil-on-tester have shown that oil convection currents are not a problem interferometrically if the oil is allowed to thermally stabilize for several hours and the oil gaps do not exceed 1 cm. The 25 cm oil-on-tester is being superceded by a 70 cm version which will undergo testing shortly.

20 CM (8") TWYMAN-GREEN INTERFEROMETER

The 20 cm Twyman-Green interferometer will be used for testing wavefront distortion at 1064 nm in the spatial filter assemblies with apertures up to 16 cm diameter and small flat reflectors. Spatial filters of large aperture will be optically evaluated in sites in the laser chain. Figure 4 shows a optical layout of the interferometer. The spatial filter assembly, which consists of an beam expander telescope with a pinhole in the image plane, is placed in one leg of the interferometer, aligned, and tested for wavefront distortion at 1064 nm.

40 CM (16") FIZEAU INTERFEROMETER

The 40 cm Fizeau interferometer will be used to test wavefront distortion in assembled rod and disk amplifiers at 6328 A. The system is a double pass interferometer with 1 fringe spacing = $\lambda/2$. The wavefront distortion at 6328 A is linearly scaleable to 1064 nm since no coatings are involved in the test parts (variations over the aperture in the layer thicknesses of coatings designed for 1064 nm prevent the interferograms of coated parts from being scaled between 633 nm and 1064 nm).

80 CM (32") FIZEAU INTERFEROMETER

An 80 cm Fizeau interferometer will be developed for use in the NOVA optical testing. It will be used to test the final optics in the laser chains, namely, turning mirror assemblies, focusing lenses, vacuum window subassemblies, polarizer subassemblies, and spatial filter assemblies. It will be used to test optics that can not be accomodated on the 20 cm Twyman-Green interferometer. The test area will be large enough to accomodate optical subassemblies up to 3 meters in length. Longer subassemblies will be tested in situ on the laser space frame. In the case of lens testing, retrospheres up to 30 cm diameter will be used to retroreflect the light through the lens in a double pass configuration. Both 1064 nm and 633 nm wavelength will be used in the interferometer.

COMPARATIVE DAMAGE TEST FACILITY

The Comparative Damage facility was developed to acceptance test glass substrates and coatings on the component level at 1064 nm. The procedure was designed to eliminate the need for beam profile measurements and to accomodate large numbers of parts. The optical layout of the Comparative Damage Test Facility is shown in Figure 5. The laser consists of an oscillator, a pulse slicer, two Nd:YAG amplifiers and a Nd:Glass amplifier. The laser system is capable of one shot every two minutes with output energies up to 5 Joules depending on the pulse length. The pulse length depends on the pulse slicer characteristics and may be varied between 1 and 10 nanoseconds. The laser beam is convergent and fluences up to 30 Joules/cm^2 can routinely be placed on the sample. The laser pulse passes through the antireflection coatings on a reference window of known damage threshold. The laser pulse also passes through the test component. If the reference films damage at a certain level and the test component doesn't damage, then the component has a higher damage threshold than the reference film, the value of which is known. By using two reference films of different damage threshold, one can bracket the threshold of the unknown. The reference film are calibrated at LLL's "absolute" Damage Test Facility.

The reference films must be moved laterally following each shot, otherwise, the damage site will, if there is one, affect the damage threshold. Damage is ascertained by an increased level of small-angle forward scatter for intense white light incident from behind the test film. An actual component from a coating run must be tested in the case of coated parts because damage thresholds of witnesses and components are frequently different.

The damage levels of a typical pair of reference films (front and back sides) are 3.1 J/cm^2 and 6.2 J/cm^2 at 1 ns. This pair of films along with the appropriate beamsplitter can be used to measure the damage threshold of films between 0.2 and 27 J/cm^2.

46 CM POLARISCOPE

A 46 cm aperture polariscope is used to determine stress-induced birefringence in large and small optics. It consists of a polarizer, analyser, $\lambda/4$ plates and mercury vapor light.

SCANNING REFLECTOMETER/TRANSMISSOMETER

The scanning reflectometer/transmissometer coil measure both reflectance and transmission of large optics at 1064 nm and throughout the range of incidence angles 10-70°. It will be capable of scanning large optics (up to 1 m). This instrument is presently in the design stage. Alignment is achieved by use of a helium neon laser which is coaxially aligned with the neodymium YAG laser beam. An AC detection scheme is used with digital electronics and a micro-computer for processing the data. The expected accuracy is $\pm$ 0.1%.

A Nd:YAG laser beam is chopped, polarized, split into a reference beam and signal beams, the latter of which is propagated to, and reflected and transmitted by the optic under test. The ratio of reflected intensity and reference intensity, I_r/I' and the ratio of transmitted intensity and reference I_t/I' is determined simultaneously while scanning the optic. With the optic completely out of the beam, the ratio of incident intensity and the reference intensity I_0/I' is measured and divided into the previous two ratios to yield the reflectance and transmission, respectively. The incident beam is chopped at a frequency which is not a harmonic of 60 Hz so as to eliminate the effect of room lights and low frequency intensity fluctuations from the laser.

SUMMARY AND CONCLUSION

The NOVA laser fusion program has introduced some new problems in the area of optical testing at Lawrence Livermore Laboratory. The size of glass that is to be used presents handling and testing problems. A 70 cm aperture oil-on-plate tester has been developed to eliminate to problems common to the conventional use of oil-on-plates. Larger interferometers are required to handle optics with apertures up to 74 cm diameter. A comparative damage facility was developed to test coated optics for damage threshold without time-consuming beam-profiling. The scanning reflectometer/transmissometer is being developed to measure reflectance and transmission at 1064 nm over large coated optics.

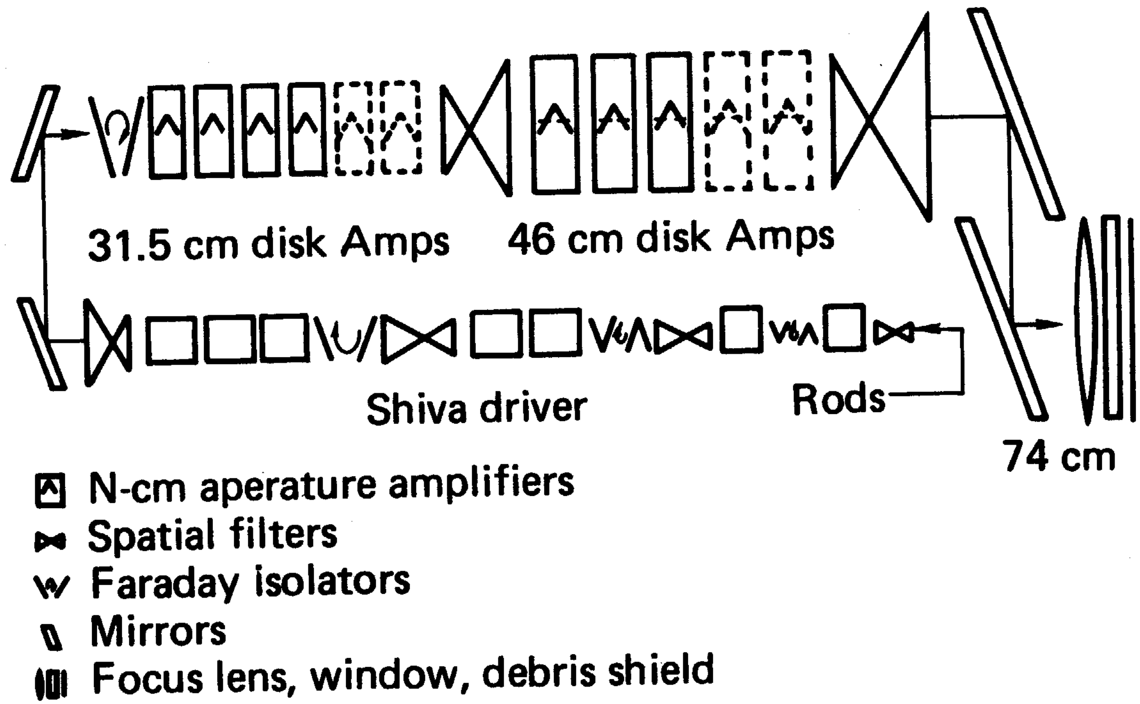

FIGURE 1

NOVA OPTICAL CHAIN

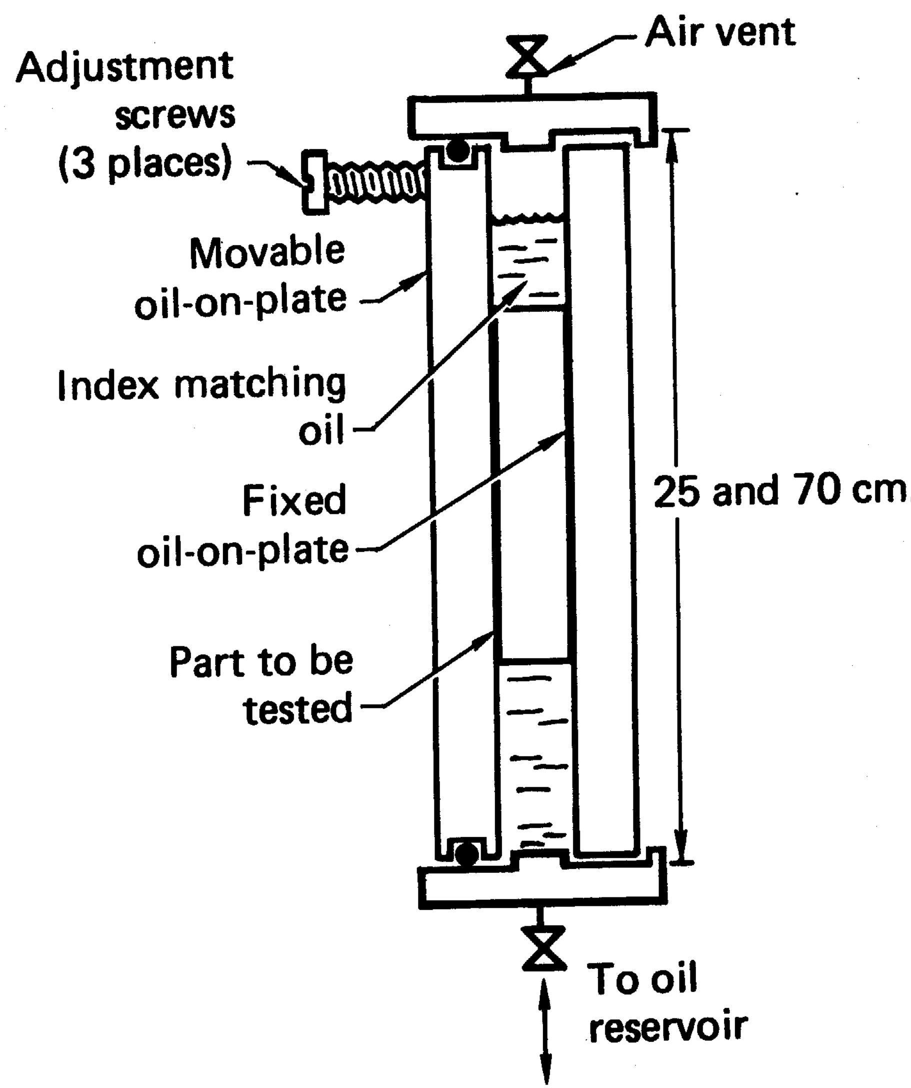

FIGURE 2

OIL-ON-PLATE TESTER

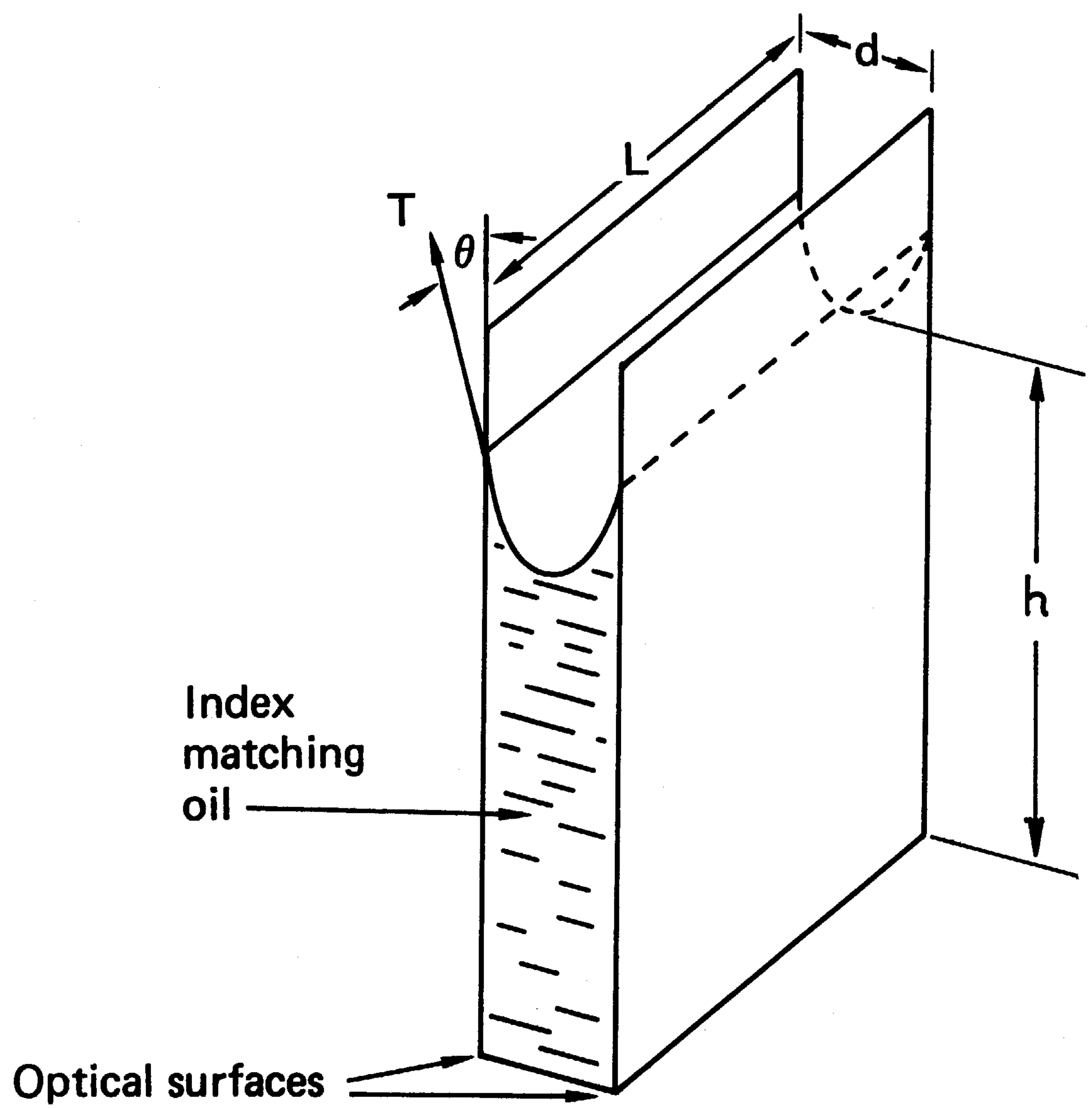

FIGURE 3

OIL CAPILLARITY

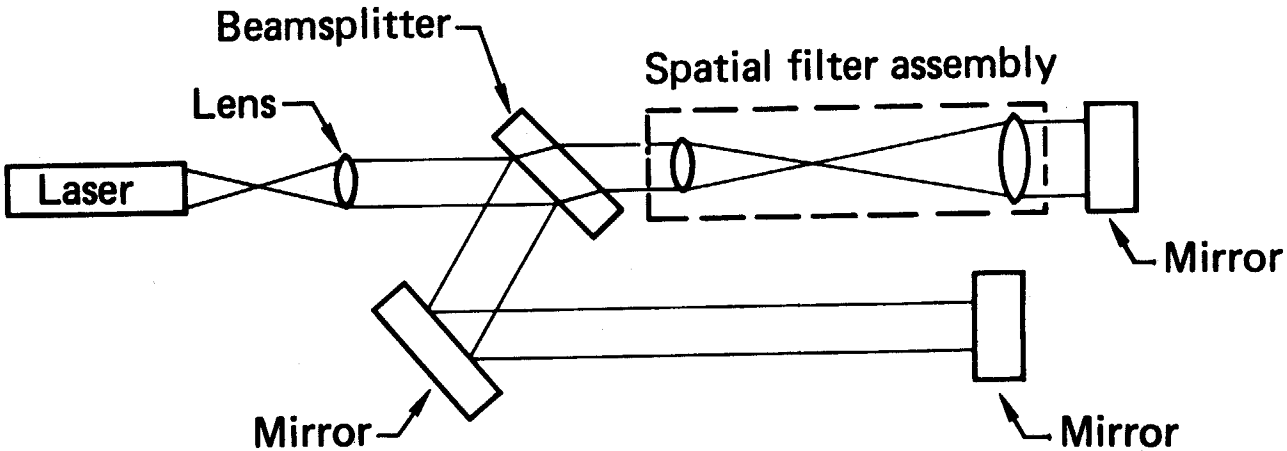

FIGURE 4

20 CM TWYMAN-GREEN INTERFEROMETER

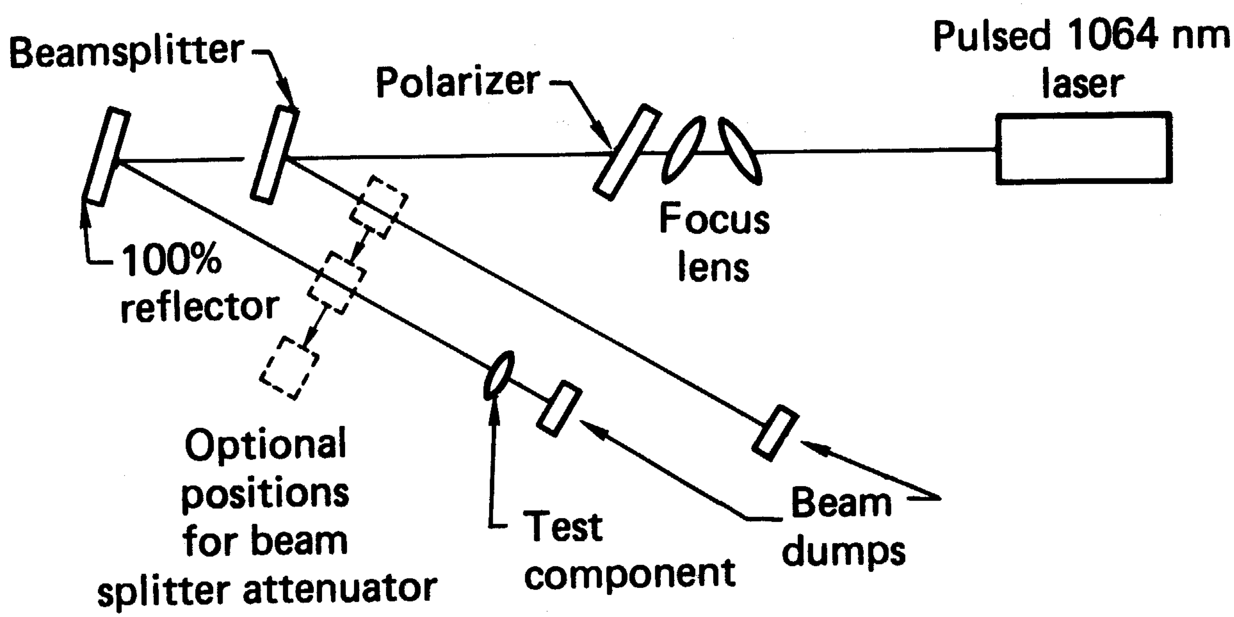

FIGURE 5

COMPARATIVE DAMAGE TEST FACILITY